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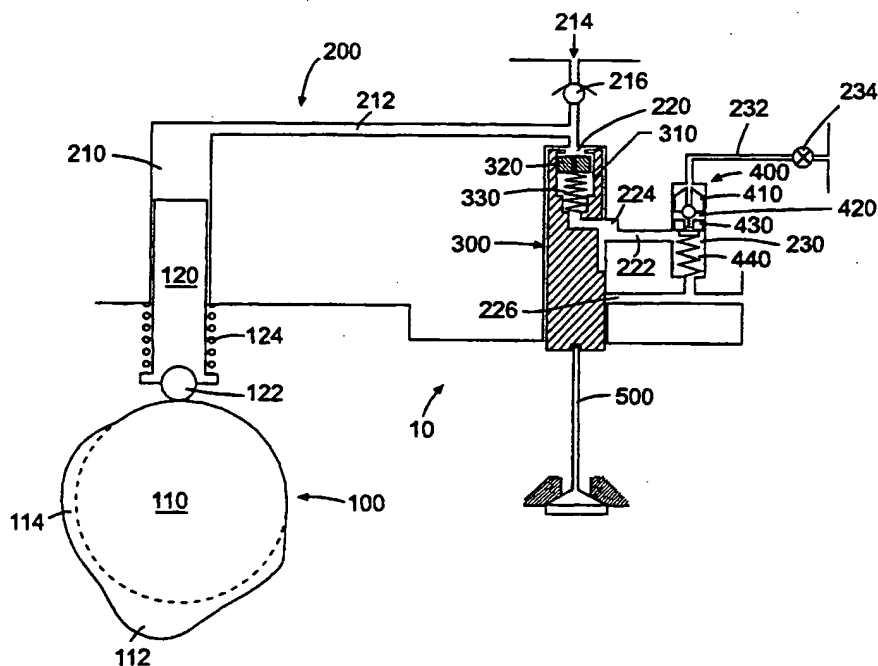
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(54) Title: CAPTIVE VOLUME ACCUMULATOR FOR A LOST MOTION SYSTEM



(57) Abstract: The present invention is directed to a method or system disclosing a captive volume in a hydraulically or pneumatically locked, or vented circuit in order to corresponding maintain, or increase the total volume of the hydraulic circuit. The structural elements of an embodiment of the present invention may include an accumulator (320) with or without a fixed solid stop (314, 316), which limits its travel. The accumulator can either be a separate entity, or as an assembly within the master (120) or slave (310) pistons.

## **CAPTIVE VOLUME ACCUMULATOR FOR A LOST MOTION SYSTEM**

### **CROSS REFERENCE TO RELATED APPLICATIONS**

The present application relates to and claims priority on U.S. Provisional Patent Application No. 60/154,473, filed September 17, 1999.

### **FIELD OF THE INVENTION**

5       The present invention relates generally to a system and method for opening at least one valve in an internal combustion engine. More specifically the invention relates to a system and method, used both during positive power and engine braking engine operating conditions, for controlling the amount of "lost motion" between the at least one valve and an assembly for opening the at least one valve.

### **BACKGROUND OF THE INVENTION**

10       Valve actuation in an internal combustion engine is required in order for the engine to produce positive power, as well as to produce engine braking. During positive power, intake valves may be opened to admit fuel and air into a cylinder for combustion. The exhaust valves may be opened to allow combustion gas to escape from the cylinder.

15       During engine braking, the exhaust valves may be selectively opened to convert, at least temporarily, an internal combustion engine of compression-ignition type into an air compressor. In doing so, the engine develops retarding horsepower to help slow the vehicle down. This can provide the operator with increased control over the vehicle and substantially reduce wear on the service brakes of the vehicle. A properly designed and adjusted compression release-type engine  
20       brake can develop retarding horsepower that is a substantial portion of the operating horsepower developed by the engine in positive power.

      In many internal combustion engines the engine cylinder intake and exhaust valves may be opened and closed by fixed profile cams in the engine, and more specifically by one or more fixed lobes which may be an integral part of each of the cams. The use of fixed profile cams makes it  
25       difficult to adjust the timings and/or amounts of engine valve lift to optimize valve opening times and lift for various engine operating conditions, such as different engine speeds.

      One method of adjusting valve timing and lift, given a fixed cam profile, has been to incorporate a "lost motion" device in the valve train linkage between the valve and the cam. Lost

motion is the term applied to a class of technical solutions for modifying the valve motion proscribed by a cam profile with a variable length mechanical, hydraulic, or other linkage assembly. In a lost motion system, a cam lobe may provide the "maximum" (longest dwell and greatest lift) motion needed over a full range of engine operating conditions. A variable length system may then  
5 be included in the valve train linkage, intermediate of the valve to be opened and the cam providing the maximum motion, to subtract or lose part or all of the motion imparted by the cam to the valve.

This variable length system (or lost motion system) may, when expanded fully, transmit all of the cam motion to the valve, and when contracted fully, transmit none or a minimum amount of the cam motion to the valve. An example of such a system and method is provided in Hu, U.S.  
10 Patent Nos. 5,537,976 and 5,680,841, which are assigned to the same assignee as the present application and which are incorporated herein by reference.

In the lost motion system of U.S. Patent No. 5,680,841, an engine cam shaft may actuate a master piston which displaces fluid from its hydraulic chamber into a hydraulic chamber of a slave piston. The slave piston in turn acts on the engine valve to open it. The lost motion system may  
15 be a solenoid valve and a check valve in communication with the hydraulic circuit including the chambers of the master and slave pistons. The solenoid valve may be maintained in a closed position in order to retain hydraulic fluid in the circuit. As long as the solenoid valve remains closed, the slave piston and the engine valve respond directly to the motion of the master piston, which in turn displaces hydraulic fluid in direct response to the motion of a cam. When the solenoid  
20 is opened temporarily, the circuit may partially drain, and part or all of the hydraulic pressure generated by the master piston may be absorbed by the circuit rather than be applied to displace the slave piston.

Previous lost motion systems have typically not utilized high speed mechanisms to rapidly vary the length of the lost motion system. Lost motion systems of the prior art have accordingly  
25 not been variable such that they may assume more than one length during a single cam lobe motion, or even during one cycle of the engine. By using a high speed mechanism to vary the length of the lost motion system, more precise control may be attained over valve actuation, and accordingly optimal valve actuation may be attained for a wide range of engine operating conditions.

The lost motion system and method of the present invention may be particularly useful in  
30 engines requiring valve actuation for both positive power and for compression release retarding and exhaust gas recirculation valve events. Typically, compression release and exhaust gas recirculation

events involve much less valve lift than do positive power related valve events. Compression release and exhaust gas recirculation events may however require very high pressures and temperatures to occur in the engine. Accordingly, if left uncontrolled (which may occur with the failure of a lost motion system), compression release and exhaust gas recirculation could result in pressure or temperature damage to an engine at higher operating speeds. Therefore, it may be beneficial to have a lost motion system which is capable of providing control over positive power, compression release, and exhaust gas recirculation events, and which will provide only positive power or some low level of compression release and exhaust gas recirculation valve events, should the lost motion system fail.

An example of a lost motion system and method used to obtain retarding and exhaust gas recirculation is provided by the Gobert, U. S. Patent No. 5,146,890 (Sept. 15, 1992) for a Method And A Device For Engine Braking A Four Stroke Internal Combustion Engine, assigned to AB Volvo, and incorporated herein by reference. Gobert discloses a method of conducting exhaust gas recirculation by placing the cylinder in communication with the exhaust system during the first part of the compression stroke and optionally also during the latter part of the inlet stroke. Gobert uses a lost motion system to enable and disable retarding and exhaust gas recirculation, but such system is not variable within an engine cycle.

The development of lost motion systems has also lead to the integration of such systems into existing engine components, as opposed to adding such systems aftermarket. One particular form of system integration that appears desirable is the integration of the lost motion system into an engine rocker arm, such as is shown in Hu, U.S. Patent No. 5,680,841. By integrating the lost motion system into the engine rocker arm, savings in weight, size, and cost may be available.

All of the foregoing developments, such as high speed lost motion actuation, and rocker arm integration, have necessitated independently and collectively, smaller, faster, more robust, more controllable, and more compliant lost motion components. One such component that requires improvement to meet the needs of these new and advanced lost motion systems is the system accumulator.

Lost motion systems may require the use of an accumulator to absorb hydraulic fluid that is quickly shuttled into and out of the system, as well as to handle the rapid pressure changes (i.e. from high pressure to low pressure and visa-versa) that occur in the system as a result of high speed actuation. The very nature of accumulators dictates that they be sufficiently robust to withstand high

and rapidly changing pressures. Compliance issues also require that the accumulators be located as closely as possible to the lost motion element with which they are in hydraulic communication. Compliance issues also mandate that the lost motion system, and to some degree, the accumulator, be adapted to bleed air from the working fluid thereby reducing the compressibility of the fluid.

5        Locating an accumulator near a lost motion element, particularly one integrated into an engine rocker arm, constrains the size and weight of the accumulator, which in turn affects the designers ability to make the accumulator robust. There is a natural inverse relationship between the robustness of an accumulator and its size and weight. The smaller and lighter the accumulator, the less robust it tends to be. Thus, the combination of loading and space requirements of  
10       accumulator pistons associated with integrated engine brakes provides a challenge to engine brake designers. In view of the foregoing, there is a need for an accumulator that is reduced in size, cost effective, sufficiently robust, capable of bleeding air, and controllable.

It has been determined that control over the amount of hydraulic fluid that the accumulator is designed to accumulate may be particularly important to the operation of the lost motion system.  
15       Without precise accumulator control, an engine valve may experience over-travel or under-travel. Moreover, imprecise accumulator control may have a negative impact on control and consistency of engine valve seating timing and velocities.

Engine valve over-travel during main events may result in valve to piston contact or the need for valve pockets in the piston. Neither valve to piston contact, nor valve pockets are desirable.  
20       Under-travel may lead to ineffective auxiliary valve events, such as compression-release events, or ineffective overlap between main intake and exhaust events. In order to reduce the likelihood of valve over-travel or under-travel, and to provide desirable valve seating timing and velocities, Applicant has developed an accumulator that absorbs a predetermined fixed volume of hydraulic fluid upon each actuation cycle of the engine brake. This accumulator provides the ability to lose  
25       the precise amount of motion provided by an engine brake lobe, or another auxiliary lobe on the exhaust cam. The loss of this precise amount of motion permits the engine valve to seat consistently, and the engine piston to be provided without pockets, while avoiding the likelihood of valve to piston contact.

Accumulator design must also take into account the undesired heating of the hydraulic fluid  
30       used in the lost motion system. Typically, engine oil is used as the working hydraulic fluid. Such engine oil enters the system already somewhat heated due to its use in the operation of the engine. The oil in the lost motion system is further heated as a result of flowing rapidly through the passages

that make up the system. It would therefore be beneficial to provide accumulators with some means of cycling hydraulic fluid through the lost motion system so that there is a constant influx of fresh cool fluid into the system.

In order to provide an accumulator with all of the foregoing beneficial characteristics, Applicant has developed an accumulator that may be integrated into a lost motion piston, such as a slave piston. Such an integrated accumulator saves space and cost due to the use of the slave piston bore as the bore for the accumulator. The integrated accumulator is also capable of being quite robust because it may be manufactured of the same strength steel used for the slave piston.

Applicant has also developed an accumulator capable of providing a precise amount of lost motion clipping of a main engine valve event. Such precise clipping is attained through use of a fixed volume or fixed displacement accumulator. Clipping without a fixed volume may either result in too much, or too little engine valve travel being removed. The latter may result in valve-to-piston contact, and the former may cause the valve to be seated at a higher velocity than desired. At a minimum, this may lead to increased engine valve seat wear, and possibly to some form of engine valve failure.

In accordance with embodiments of the present invention, it is contemplated that the accumulator system may be located in a master piston, a slave piston, or separate piston. It is further contemplated that in accordance with the present invention the accumulator system may be located within a rocker arm assembly of an engine rocker brake.

## OBJECTS OF THE INVENTION

It is therefore an object of the present invention to provide a lost motion system accumulator with improved robustness for its size.

It is another object of the present invention to provide a lost motion system accumulator that reduces accumulator bore wear.

It is another object of the present invention to reduce the package size of a lost motion system accumulator.

It is a further object of the present invention to provide a more cost effective method for packaging a lost motion system accumulator.

It is still another object of the present invention to reduce some of the variances of bleed rate for a lost motion system accumulator due to pressure differentials.

It is yet another object of the present invention to improve braking performance by improving compliance of a lost motion system accumulator.

It is still yet another object of the present invention to provide a lost motion system accumulator capable of venting and/or absorbing a fixed volume of hydraulic fluid to eliminate  
5 valve-to-piston clearance issues.

It is still another object of the present invention to provide a lost motion system accumulator with desirable air bleeding and hydraulic fluid circulation capabilities.

It is still another object of the present invention to provide a lost motion system accumulator that will reduce engine valve spring stresses as a result of fixed volume accumulator.

10 It is still another object of the present invention to provide a lost motion system accumulator that provides lower engine valve seating velocities.

It is still another object of the present invention to provide a lost motion system accumulator that provides more consistent valve seating timing and velocities.

Additional objects and advantages of the invention are set forth, in part, in the description  
15 which follows and, in part, will be apparent to one of ordinary skill in the art from the description and/or from the practice of the invention.

### SUMMARY OF THE INVENTION

In response to the foregoing challenge, Applicant has developed an innovative, economical  
20 method or system for providing a lost motion accumulator that uses a captive (fixed) volume that can be selectively hydraulically or pneumatically locked, or vented in order to maintain or increase the total volume of the lost motion system.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only, and are not restrictive of the invention as claimed.  
25 The accompanying drawings, which are incorporated herein by reference, and which constitute a part of this specification, illustrate certain embodiments of the invention, and together with the detailed description serve to explain the principles of the present invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

30 The invention will now be described in conjunction with the following drawings in which like reference numerals designate like elements and wherein:

Fig. 1 is a schematic view of a captive volume accumulator system in accordance with a first embodiment of the present invention.

Fig. 2 is a schematic view of a captive volume accumulator system in accordance with a second embodiment of the present invention.

5 Fig. 3 is a schematic view of a captive volume accumulator system in accordance with a third embodiment of the present invention.

Fig. 4 is a schematic view of a captive volume accumulator system in accordance with a fourth embodiment of the present invention.

10 Fig. 5 is a schematic view of a captive volume accumulator system in accordance with a fifth embodiment of the present invention.

Fig. 6 is a graphical representation of a valve lift profile according to an embodiment of the present invention.

Fig. 7 is a schematic view of an accumulator control valve in an "OFF" position in accordance with a sixth embodiment of the present invention.

15 Fig. 8 is a schematic view of the control valve of Fig. 7 in an "ON" position.

Fig. 9 is a schematic view of an accumulator control valve in an "OFF" position in accordance with a seventh embodiment of the present invention.

Fig. 10 is a schematic view of the control valve of Fig. 9 in an "ON" position.

20 Fig. 11 is a schematic view of an accumulator control valve in an "OFF" position in accordance with an eighth embodiment of the present invention.

Fig. 12 is a schematic view of the control valve of Fig. 11 in an "ON" position.

Fig. 13 is a detailed view of the slave piston and accumulator assembly shown in Fig. 1.

Fig. 14 is a schematic view of a captive volume accumulator system in accordance with a ninth embodiment of the present invention.

25 Fig. 15 is a schematic view of a captive volume accumulator system in accordance with a tenth embodiment of the present invention in which the system is integrated into an engine rocker arm.

Fig. 16 is a view of the tenth embodiment shown in Fig. 15 along section C-C.

30 Figs. 17-19 are illustrations of a captive volume accumulator system in accordance with an eleventh embodiment of the present invention in which the system is integrated into an engine rocker arm.



## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of the present invention is shown as accumulator system 10 in Fig. 1. The system 10 includes an energy source 100, which provides the necessary energy to operate at least one engine valve 500. The energy source 100 supplies energy to an energy transfer assembly 200. The energy transfer assembly 200 transfers energy derived from the energy source 100 to an actuating assembly 300, which activates the at least one engine valve 500. A control assembly 400 may be provided to control the amount of energy and/or the amount of motion transferred by the energy transfer assembly 200 to the actuating assembly 300.

With continued reference to Fig. 1, the energy source 100 may comprise a cam 110 as well as other typical valve train elements. The cam 110 may have at least one lobe 112 thereon to provide energy to perform a main engine valve event and at least one lobe 114 to provide energy to perform a secondary engine valve event. The main engine valve event may be a main exhaust event. The secondary engine valve event may include a compression-release braking event and/or an exhaust gas recirculation event. The present invention, however, is not limited to the use of a cam 110 as an energy source to operate the at least one engine valve 500, rather, it is contemplated that other suitable sources of energy may be employed without departing from the scope of the invention.

The cam 110 may be in operational contact with a roller follower 122 provided on a master piston 120. The master piston 120 may be slidably disposed in a master piston bore 210 and biased into contact with the cam 110 by the master spring 124. The master piston bore 210 may be charged with hydraulic fluid from a low pressure supply passage 214. Oil supplied by passage 214 flows into the system 10, past a check valve 216, and through a passage 212. Oil from the passage 212 fills the master piston bore 210 and enters the slave piston bore 220.

A slave piston 300 may be slidably disposed in the slave piston bore 220. The slave piston 300 may include a slave piston body 310, an accumulator piston 320, and an accumulator spring 330. A detailed illustration of the upper portion of the slave piston 300 is shown in Fig. 13. As shown in Fig. 13, the travel of the accumulator piston 320 may be limited by an upper shoulder 314 and a lower shoulder 316. The upper shoulder 314 may define a central opening 312 through which hydraulic fluid pressure can be applied to the accumulator piston 320. The upper shoulder 314 may control the maximum volume of oil that may be contained in the accumulator chamber 315. The

arrangement shown in Fig. 13 provides for automatic lash take up between the slave piston 300 and the engine valve 500.

The accumulator piston 320 may include a bleed passage 322 that may provide controlled or resultant leakage into the accumulator chamber 315. The accumulator spring 330 may bias the  
5 accumulator piston 320 against the upper shoulder 314 when low pressure oil is provided to the slave piston bore 220. The accumulator spring 330 may seat on an internal land 316.

A passage 317 provides hydraulic communication between the chamber 315 containing the accumulator piston 320 and the sidewall of the slave piston body 310. An annulus or recess 319 may be provided in the slave piston sidewall to facilitate a predetermined amount of hydraulic  
10 communication between the accumulator chamber 315 and the control valve bore 230 (shown in Fig. 1).

With renewed reference to Fig. 1, a control passage 222 provides hydraulic communication between the control valve bore 230 and the slave piston bore 220. The control passage 222 may include an enlarge portion 224 that is designed to provide a predetermined amount of hydraulic  
15 communication between the slave piston and control valve bores.

A control valve 400 may be slidably disposed in the control valve bore 230. The control valve may comprise a check valve body 410, a check ball 420, a check ball spring 430, and a control valve spring 440. A first end of the control valve bore 230 may connect to a control fluid supply passage 232 that selectively supplies hydraulic fluid to the control valve 400 under the control of  
20 a solenoid valve 234. A second end of the control valve bore 230 may connect to a vent passage 226 that communicates with the atmosphere or a second accumulator (not shown). If the vent passage 226 connects to a second accumulator, the vented fluid may eventually be returned to the fluid supply, and thus the fluid supply passage 232. The control valve 400 may either be a fast or slow acting mechanical, electro-mechanical, electro-magnetic, pneumatic, or hydraulic valve that  
25 controls the communication of the accumulator chamber 315 with the vent passage 226. The check valve 410 portion of the control valve 400 can also supply low pressure oil to the system 10.

With continued reference to Fig. 1, the control valve 400 is in an "off" position. The off position is defined as that in which the solenoid valve 234 does not have power supplied to it and the control valve body 410 is at the resting position. When in the off position, the control valve 400  
30 permits hydraulic communication between the accumulator chamber 315 and the vent passage 226 by way of the passage 222. The off position of the control valve 400 is used to provide positive power engine valve operation (i.e. no compression-release braking).

During positive power operation, the system 10 is charged with low pressure oil from the passage 214. The check valve 216 prevents the oil provided to the master piston bore 210 and the slave piston bore 220 from flowing back towards the low pressure supply, and thus provides automatic lash take up. The oil provided from the passage 214 is not sufficiently pressurized to  
5 depress the accumulator spring 330. Thus, the accumulator piston 320 remains biased against the upper shoulder 314 when the master piston 120 is at base circle (as shown).

As the cam 110 rotates, the master piston 120 is displaced upward by a secondary lobe 114. The displacement of the master piston 120 causes the accumulator piston 320 to be correspondingly displaced downward against the bias of the accumulator spring 330 into the accumulator chamber  
10 315 relative to the slave piston body 310. From an observation point outside of the slave piston 300, the accumulator piston 320 may move downward to some degree and the slave piston body 310 may move upward to some degree, in accordance with the hydraulic ratios of these elements that is dependent on the relative diameters of the slave piston bore 220 and the accumulator chamber 315. Relative movement of the accumulator piston 320 and the slave piston body 310 causes the  
15 accumulator spring 330 to be depressed because as between it and the engine valve spring (not shown) it provides a lower biasing force. The volume of the accumulator chamber 315 is designed to fully absorb the oil displaced by the master piston 120 as a result of encountering the secondary lobe 114. The lower shoulder 316 may be located such that the accumulator piston 320 engages the lower shoulder just as the maximum displacement produced by the secondary lobe 114 is applied  
20 to the master piston 120.

After encountering the secondary lobe 114, the master piston 120 is displaced further by the main event lobe 112. The additional displacement of oil by the master piston 120 can no longer be absorbed by the accumulator piston 320 because it is already in contact with the lower shoulder 316 as a result of the displacement caused by the secondary lobe 114. Thus, the additional displacement  
25 of hydraulic fluid by the master piston 120 causes the slave piston body 310 to slide downward in the slave piston bore 220 against the bias of the engine valve spring (not shown). In this manner, the main event lobe 112 may converted to a main event opening motion for the engine valve 500.

Seating of the engine valve 500 occurs as the master piston 120 follows the cam 110 into the saddle of the second base circle (i.e. the secondary lobe 114). As the master piston 120 follows  
30 the cam 110 onto the first base circle, the slave piston 310 and the accumulator piston 320 return to their upper rest positions.

In the positive power mode, the bleed passage 322 is constantly operational. This passage provides system cooling by continuously replacing heated, worked oil with fresh, cooler oil from the supply passage 214.

5 In order to place the engine in compression-release braking mode, the solenoid valve 234 may be actuated (or de-actuated, depending on whether the solenoid is arranged as normally open or normally closed). Actuation of the solenoid valve 234 causes low pressure hydraulic fluid to be applied to the control valve 400 through the passage 232. The oil pressure applied to the control valve 400 causes it to be displaced downward against the bias of the control valve spring 440. In this position the control valve 400 blocks hydraulic communication between the passage 222 and  
10 the vent passage 226. The check ball 420 of the control valve 400, however, permits the one way flow of oil into the high pressure circuit (passage 222 and slave piston bore 220), but not back out of the high pressure circuit. The check ball 420 allows oil to fill the accumulator chamber 315 as the accumulator piston 320 re-attains its upper most position when the cam 110 returns to base circle.

15 When the solenoid valve 234 is "on", and the cam 110 is at base circle, the accumulator piston 320 is hydraulically locked into its upper position against the upper shoulder 314. As the cam 110 rotates, the master piston 120 is first displaced upward by the secondary lobe 114. Because the accumulator piston 320 is locked into position, the displacement of the master piston 120 by the secondary lobe 114 causes a corresponding downward displacement of the slave piston 310. The  
20 downward motion of the slave piston 310 may in turn open the engine valve 500 for a compression-release event.

After the compression-release braking event occurs, the master piston may be further displaced by main event lobe 112 on the cam 110. The main event lobe 112 cause the slave piston 320 to be further displaced, opening the engine valve 500 for its main event. At a certain point on  
25 the main event lobe profile, the recess 319 provided in the slave piston 310 comes into hydraulic communication with the vent passage 226. When this communication occurs, the high pressure hydraulic fluid locking the accumulator piston 320 into its upper position is released to atmosphere or a second accumulator. This permits the accumulator piston 320 to move downward in the accumulator chamber 315 relative to the slave piston body 310 until it comes to rest on the lower  
30 shoulder 316. Thus, communication of the recess 319 with the vent passage 226 permits the accumulator piston 320 to absorb the precise amount of additional motion provided by the secondary cam lobe 114. In this manner, the main event motion provided to the engine valve 500 during

engine braking operation is limited to the same amount of motion that is provided by a main event during positive power operation. Therefore, the present invention provides the same valve-to-piston clearance during positive power and engine braking operation.

It is appreciated that the afore-described process could be modified such that an exaggerated  
5 main exhaust event is provided by maintaining the control valve 400 in its positive power position during engine braking.

The bleed passage 322 provided in the accumulator piston 320 does not affect the ability of the accumulator piston to be hydraulically locked, which eliminates the variability of orifice bleeding that may ordinarily result from system pressure variations. When the accumulator chamber  
10 315 is vented through the vent passage 226, however, the bleed passage 322 is also able to vent. A certain amount of oil will be bled through the system each time the accumulator chamber 315 is placed in communication with the vent passage 226. The position of the vent passage 226 may be selected so as to be anywhere in the range of valve lift for the main event, as long as it is less than the peak lift minus the lost motion portion of the lift. Oil for hydraulic lash adjustment and recovery  
15 from lost oil may be regained through the high-pressure check valve contained in the control valve 400.

The engine valve 500 will seat as the master piston 120 follows the cam 110 back into the saddle of the second base circle (i.e. secondary event 114). As the master piston 120 begins to travel down the last ramp of the secondary event 114 to the first base circle, the accumulator piston 320  
20 will reset to its upper position under the influence of oil provided through the control valve 400.

Fig. 6 is a graphical representation of valve lift as disclosed in the present invention. In a lost motion system, where the cam profile has two events: one which can be suppressed, and the second is additive to the first (see Fig. 6 - Braking Lift). This leads to valve to piston clearance issues. A method of eliminating this over-travel, is to vent a fixed volume of oil. If the volume of  
25 oil is equal to the amount of lift of the first bump, then the valve will seat as shown. This process can be accomplished with any lost motion system and can use any means to enact the venting of the hydraulic volume.

A second embodiment of the present invention is shown in Fig. 2, in which like reference numerals refer to like elements. The operation of the system shown in Fig. 2 is similar to that of the system shown in Fig. 1. In Fig. 2, a spool valve 412 that includes a check valve at one end serves  
30 as the control valve 400. When the spool valve 412 is in the position shown, the accumulator piston 320 is free to be displaced in the accumulator chamber 315 as the result of high pressure received

through the passage 212. Displacement of the accumulator piston 320 causes the oil in the chamber 315 to be vented through the vent passage 226.

The system shown in Fig. 2 may provide compression-release braking by actuating the solenoid valve 234, which in turn causes oil to flow through the passage 232 and displace the spool valve 412 upward. This displacement of the spool valve 412 blocks communication between the passage 222 and the vent passage 226, thereby hydraulically locking the accumulator piston 320 into its upper position. One way flow of oil into the accumulator chamber 315 is permitted by the check valve end 410 of the control valve 400. Unlocking of the accumulator piston 320 during the main engine valve event may occur as a result of either communication between the slave piston passage 317 and the secondary vent passage 228, or the high speed actuation of the spool valve 412 with an mechanical, electro-mechanical, electro-magnetic, pneumatic, or hydraulic actuator. The secondary vent passage 228 may communicate with the vent passage 226.

The system shown in Fig. 2 (as well as that shown in Figs. 3 and 5) may also benefit from the isolation of the spring 440 from the hydraulic pulses that may occur in the vent passage 226.

A third embodiment of the present invention is shown in Fig. 3, in which like reference numerals refer to like elements. The operation of the system shown in Fig. 3 is similar to that of the system shown in Fig. 2. In Fig. 3, a spool valve 412 serves as the control valve 400. The spool valve 412 provides communication with the slave piston bore 220 alternatively with a vent passage 226 (during positive power operation) or with a constant checked supply of low pressure oil from a low pressure passage 214 (during engine braking operation). When the spool valve 412 is in the position shown, the accumulator piston 320 is free to be displaced in the accumulator chamber 315 as the result of high pressure received through the passage 212. Displacement of the accumulator piston 320 causes the oil in the chamber 315 to be vented through the vent passage 226.

With continued reference to Fig. 3, compression-release braking operation may be provided by actuating the solenoid valve 234, which in turn causes oil to flow through the passage 232 and displace the spool valve 412 downward. This displacement of the spool valve 412 blocks communication between the passage 222 and the vent passage 226, and opens communication between the supply passage 214 and the passage 222, thereby hydraulically locking the accumulator piston 320 into its upper position. One way flow of oil into the accumulator chamber 315 is permitted by the check valve 216. Unlocking of the accumulator piston 320 during the main engine valve event may occur as a result of either communication between the slave piston passage 317 and the secondary vent passage 228, or the high speed actuation of the spool valve 412 via high speed

actuation of the solenoid valve 234. The secondary vent passage 228 may communicate with the vent passage 226. The control valve 400 may either be a fast or slow acting mechanical, electro-mechanical, electro-magnetic, pneumatic, or hydraulic valve that controls the communication of the accumulator chamber 315 with the vent passage 226.

5 A fourth embodiment of the present invention is shown in Fig. 4, in which like reference numerals refer to like elements. In this embodiment, the spool valve 412 alternatively connects the passage 222 (and thus the accumulator chamber 315) to either the vent passage 226 or a high pressure hydraulic fluid supply passage 212. The solenoid valve 234 may control the position of the spool valve 412. When the solenoid valve 234 blocks the flow of hydraulic fluid into the control  
10 valve bore 230, the spool valve 412 is biased upward and provides communication between the passage 222 and the vent passage 226. When the solenoid valve 234 supplies hydraulic pressure, the spool valve 412 is biased down into the position shown so that the vent passage 226 is closed and the high-pressure passage 212 is placed in communication with the accumulator chamber 315.

A fifth embodiment of the present invention is shown in Fig. 5, in which like reference  
15 numerals refer to like elements. With reference to Fig. 5, a spool valve 412 with a bleed fill may be provided. During engine braking operation, the spool valve 412 is displaced upward against the bias of the control valve spring 440. In this position, the accumulator chamber 315 is permitted to vent through the vent passage 226 to either the atmosphere, or a second accumulator that is connected back to the high-pressure circuit, to aid in re-fill. During positive power operation, the  
20 spool valve 412 is positioned as shown so that the vent passage 226 is blocked. The accumulator chamber 315 may be filled by leakage from the high-pressure passage 212 past the accumulator piston 320. This leakage fill feature is further enhanced by the incorporation of a constant bleed passage 322 (shown in Fig. 1) into the accumulator piston 320.

With reference to Fig. 7, an accumulator control valve 400 configured in accordance with  
25 a seventh embodiment of the present invention is shown, in which like reference numerals refer to like elements. With reference to Fig. 7, the spool valve 412 may be controlled via the application of low pressure hydraulic fluid from the passage 232. The spool valve 412 may provide the passage 222 (connected to the accumulator chamber 315) with communication alternatively with the atmosphere through the vent plate 238 or with the checked low pressure supply via the check valve  
30 216. The passage 222 is offset from the passage 232 and the spool valve 412 is positioned so that the low pressure supply passage does not ever communicate with the vent plate 238. As a result of the foregoing arrangement, the application of low pressure hydraulic fluid in the passage 232

immediately causes the spool valve 412 to index upward and block communication between the passage 222 and the vent plate 238. Fig. 7 shows the spool valve 412 in the position required for positive power operation (primary mode) of the lost motion system. Fig. 8 shows the same spool valve 412 as is shown in Fig. 7 in the position required for engine braking operation (secondary mode). The control valve 400 may either be a fast or slow acting mechanical, electro-mechanical, electro-magnetic, pneumatic, or hydraulic valve that controls the communication of the accumulator chamber 315 with the vent passage 226.

With reference to Fig. 9, an accumulator control valve 400 configured in accordance with a sixth embodiment of the present invention is shown, in which like reference numerals refer to like elements. With reference to Fig. 9, the spool valve 412 may be controlled via the application of low pressure hydraulic fluid from the passage 232. The spool valve 412 may provide the passage 222 (connected to the accumulator chamber 315) with communication alternatively with the atmosphere through the vent plate 238 or with the checked low pressure supply via the check valve 216. The passage 222 is located directly across from the passage 232, which simplifies manufacturing of the system. The spool valve 412 is positioned so that the passage 232 communicates with the vent plate 238 when the spool valve is in an "off" position. As a result of the foregoing arrangement, the application of low pressure hydraulic fluid in the passage 232 does not immediately cause the spool valve 412 to index upward and block communication between the passage 222 and the vent plate 238. Spool valve 412 indexes upward only after the combined flow of oil past the check valve 216 and the vent plate 238 backs up sufficiently to allow hydraulic pressure to build underneath the spool valve. Fig. 9 shows the spool valve 412 in the position required for positive power operation of the lost motion system. Fig. 10 shows the same spool valve 412 as is shown in Fig. 9, in the position required for engine braking operation. The control valve 400 may either be a fast or slow acting mechanical, electro-mechanical, electro-magnetic, pneumatic, or hydraulic valve that controls the communication of the accumulator chamber 315 with the vent passage 226.

With reference to Fig. 11, an accumulator control valve 400 configured in accordance with a seventh embodiment of the present invention is shown, in which like reference numerals refer to like elements. With reference to Fig. 11, the slug 414 may be controlled via the application of low pressure hydraulic fluid from the passage 232. The slug 414 may selectively block the flow of hydraulic fluid from the accumulator chamber 315 to the atmosphere through the vent plate 238. Actuation of the control valve 400 occurs due to the combination of the length of the passage 232 that connects to the accumulator bore 220 and the restriction provided by the check valve 216 being



sufficient to delay the actuation of the slave piston body until after the slug 414 is indexed upward to block the vent plate 238. Fig. 11 shows the slug 414 in the position required for positive power operation of the lost motion system. Fig. 12 shows the same slug 414 as is shown in Fig. 11, in the position required for engine braking operation. The control valve 400 may either be a fast or slow acting mechanical, electro-mechanical, electro-magnetic, pneumatic, or hydraulic valve that controls the communication of the accumulator chamber 315 with the vent passage 226.

In accordance with variations of the present invention, an accumulator vent passage may be placed in communication with the high pressure circuit in the lost motion system 10 through the motion of the slave piston 310, which contains a window to either the atmosphere, or a second accumulator that is connected back to the high-pressure circuit, to aid in re-fill. With reference to Fig. 14, in an alternative embodiment of the invention, an accumulator vent passage may be exposed through the motion of the master piston 120, which contains a window to either the atmosphere or a second accumulator that is connected back to the high-pressure circuit, to aid in re-fill. This may effectively reset the engine valve 500.

Figs. 15 and 16 show the slave piston 300 and control valve 400 arrangement of Fig. 4 arranged in a rocker arm 600. Fig. 15 also illustrates the use of a preferred accumulator piston 320 that includes a piston head 324 and a piston stem 326, and dual accumulator springs 330 and 332. The operation of the slave piston 300 and the control valve 400 is the same as that described in connection with Fig. 4 except that the downward force applied to the slave piston is provided by the rotation of the rocker arm 600 in the system shown in Figs. 15 and 16, as opposed to the master piston 120 in the system of Figs. 1 and 4. It is appreciated that any of the slave piston/control valve arrangements shown in Figs. 1-5 and 7-14 may be integrated into a rocker arm as shown in Figs. 15 and 16. The control valve 400 may either be a fast or slow acting mechanical, electro-mechanical, electro-magnetic, pneumatic, or hydraulic valve that controls the communication of the accumulator chamber 315 with the vent passage 226.

Fig. 17-19 show the slave piston 300 and control valve 400 arrangement of Fig. 1 arranged in a rocker arm 600.

It will be apparent to those skilled in the art that various modifications and variations can be made in the construction, configuration, and/or operation of the present invention without departing from the scope or spirit of the invention. For example, in the embodiments mentioned above, various changes may be made to the accumulator without departing from the scope and spirit of the invention. Further, it may be appropriate to make additional modifications or changes to the

hydraulic system without departing from the scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of the invention provided they come within the scope of the appended claims and their equivalents.

**What is Claimed:**

1. An actuating system for operating at least one valve of an engine during a plurality of engine operating modes, said system comprising:

energy means for supplying energy to operate the at least one valve during the plurality of engine operating modes;

5 valve actuation means for actuating the at least one valve during said the plurality of engine operating modes;

energy transfer means for transferring energy from said energy means to said valve actuation means; and

control means for controlling the amount of energy transferred from said energy means to  
10 said valve actuation means to control the actuation of the at least one valve during the plurality of engine operating modes.

2. The actuating system according to Claim 1, wherein said valve actuation means, said energy transfer means and said control means cooperate to provide lost motion valve actuation of the at least one valve.

3. The actuating system according to Claim 1, wherein said energy transfer means transfers all of the energy derived from said energy supply means during one operating mode.

4. The actuating system according to Claim 3, wherein said one operating mode is an auxiliary operating mode.

5. The actuating system according to Claim 3, wherein said energy transfer means transfers a portion of the energy derived from said energy supply means during a second operating mode.

6. The actuating system according to Claim 1, wherein said valve actuation means includes an accumulator piston slidably disposed in a slave piston.

7. The actuating system according to Claim 1, wherein said valve actuation means includes a selectively actuatable accumulator.

8. The actuating system according to Claim 7, wherein said valve actuation means, said energy transfer means and said control means cooperate to provide lost motion valve actuation of the at least one engine valve.

9. The actuating system according to Claim 7, wherein said selectively actuatable accumulator is in a locked position during one operating mode such that substantially all of the energy from the energy means is transferred to said valve actuation means.

10. The actuating system according to Claim 9, wherein said selectively actuatable accumulator has a fixed volume.
11. The actuating system according to Claim 6, wherein said accumulator piston includes a piston head and a piston stem.
12. The actuating system according to Claim 8, wherein said selectively actuatable accumulator is in an unlocked position during one operating mode such that only a portion of the energy from the energy means is transferred to said valve actuation means.
13. The actuating system according to Claim 6, further comprising a bleed passage extending through the accumulator piston.
14. The actuating system according to Claim 7, wherein said control means includes supply means for supplying a fluid to said selectively actuatable accumulator.
15. The actuating system according to Claim 7, wherein said control means further includes venting means for venting the fluid from said selectively actuatable accumulator at a predetermined time.
16. The actuating system according to Claim 7, wherein said selectively actable accumulator is incorporated into a piston assembly.
17. The actuating system according to Claim 7, wherein said selectively actable accumulator is incorporated into a piston assembly, and wherein said control means further includes venting means for venting the fluid from said selectively actuatable accumulator at a predetermined position of said piston assembly.
18. The actuating system according to Claim 16, wherein said selectively actuatable accumulator has a fixed volume.
19. The actuating system according to Claim 14, wherein said supply means supplies fluid to said selectively actuatable accumulator to maintain said accumulator in a locked position in one operating mode.
20. The actuating system according to Claim 1, wherein said valve actuation means includes a disk-shaped accumulator piston slidably disposed in a slave piston.
21. The actuating system according to Claim 1, wherein said control means comprises a spool valve.
22. The actuating system according to Claim 21, wherein said spool valve includes an internal check valve.

23. The actuating system according to Claim 21, further comprising a spring biasing said spool valve into a position for positive power engine valve operation.
24. The actuating system according to Claim 21, wherein said control means further comprises a check valve located externally of said spool valve.
25. The actuating system according to Claim 21, wherein said control means further includes selectively operable fluid supply means for selectively supplying fluid to said supply means.
26. The actuating system according to Claim 23, wherein said control means further comprises an hydraulic vent, and wherein said biasing spring is isolated from hydraulic fluid flow through said vent.
27. The actuating system according to Claim 21, wherein said control means further includes a solenoid operated valve for selectively controlling fluid supply to said spool valve.
28. The actuating system according to Claim 21, wherein said valve actuation means includes an accumulator piston slidably disposed in a slave piston.
29. The actuating system according to Claim 28, wherein said accumulator piston comprises a piston head and a piston stem.
30. The actuating system according to Claim 29, further comprising at least one spring disposed between said accumulator piston and said slave piston.
31. The actuating system according to Claim 29, further comprising a bleed passage extending through the accumulator piston.
32. The actuating system according to Claim 21, wherein said control means further includes venting means for venting a predetermined amount of fluid from said valve actuation means at predetermined times during the plurality of engine operating conditions.
33. The actuating system according to Claim 32, wherein said valve actuation means comprises a piston assembly disposed in a bore, a selectively actuatable accumulator disposed in the piston assembly, and wherein said venting means vents the fluid from said selectively actuatable accumulator at a predetermined position of said piston assembly in the bore.
34. The actuating system according to Claim 1, wherein said energy transfer means comprises an hydraulic link between a master piston and a slave piston.
35. The actuating system according to Claim 1, wherein said energy transfer means comprises a rocker arm and said valve actuation means comprises the combination of a slave piston and stem-shaped accumulator piston.

36. The actuating system according to Claim 32, further comprising a fluid recovery system, and wherein said venting means vents said fluid to the fluid recovery system.
37. The actuating system according to Claim 36, wherein said fluid recovery system is connected to an additional accumulator assembly.
38. The actuating system according to Claim 36, wherein said fluid recovery system is connected to said supply means.
39. The actuating system according to Claim 36, wherein said fluid recovery system is connected to a reservoir.
40. The actuating system according to Claim 36, wherein said fluid recovery system is connected to a supplemental fluid supply.
41. The actuating system according to Claim 21, wherein said energy transfer means comprises a rocker arm, and wherein said spool valve is disposed within said rocker arm and wherein said spool valve incorporates a check valve.
42. The actuating system according to Claim 41, further comprising a spring positioned to bias said spool valve into an open position.
43. The actuating system according to Claim 41, wherein said control means further comprises a check valve disposed within said rocker arm and located externally of said spool valve.
44. The actuating system according to Claim 41, further comprising a spring biasing said spool valve into a position for positive power engine valve operation..
45. The actuating system according to Claim 41, wherein said control means further includes selectively operable fluid supply means for selectively supplying fluid to said supply means.
46. The actuating system according to Claim 44, wherein said control means further comprises an hydraulic vent, and wherein said biasing spring is isolated from hydraulic fluid flow through said vent.
47. The actuating system according to Claim 41, wherein said control means further includes a solenoid operated valve for selectively controlling fluid supply to said spool valve.
48. The actuating system according to Claim 41, wherein said valve actuation means includes an accumulator piston slidably disposed in a slave piston.
49. The actuating system according to Claim 48, wherein said accumulator piston comprises a piston head and a piston stem.

50. The actuating system according to Claim 49, further comprising at least one spring disposed between said accumulator piston and said slave piston.

51. The actuating system according to Claim 49, further comprising a bleed passage extending through the accumulator piston.

52. The actuating system according to Claim 41, wherein said control means further includes venting means for venting a predetermined amount of fluid from said valve actuation means at predetermined times during the plurality of engine operating conditions.

53. The actuating system according to Claim 52, wherein said valve actuation means comprises a piston assembly disposed in a bore, a selectively actuatable accumulator disposed in the piston assembly, and wherein said venting means vents the fluid from said selectively actuatable accumulator at a predetermined position of said piston assembly in the bore.

54. The actuating system according to Claim 41, wherein said valve actuation means comprises a selectively actuatable accumulator.

55. The actuating system according to Claim 1, wherein said energy supply means comprises a cam assembly.

56. The actuating system according to Claim 55, wherein said energy transfer means includes a piston assembly, wherein said control means includes a selectively actuatable accumulator, said actuatable accumulator being located within said piston assembly.

57. The actuating system according to Claim 56, wherein said valve actuation means, said energy transfer means and said control means cooperate to provide lost motion valve actuation of the at least one valve.

58. The actuating system according to Claim 57, wherein said selectively actuatable accumulator is in a locked position during one operating mode.

59. The actuating system according to Claim 58, wherein said one operating mode is one of a primary operating mode and an auxiliary operating mode.

60. The actuating system according to Claim 1, wherein said valve actuation means includes a piston assembly and said energy transfer means includes a hydraulic circuit, wherein said control means includes a selectively actuatable accumulator, said actuatable accumulator being located within said slave piston assembly.

61. The actuating system according to Claim 60, wherein said valve actuation means, said energy transfer means and said control means cooperate to provide lost motion valve actuation of the at least one valve.

62. The actuating system according to Claim 60, wherein said selectively actuatable accumulator is in a locked position during one operating mode.

63. The actuating system according to Claim 60, wherein said one operating mode is one of a primary operating mode and an auxiliary operating mode.

64. The actuating system according to Claim 1, wherein said energy transfer means includes a first piston assembly and a hydraulic fluid circuit, and said valve actuation means includes a second piston assembly, wherein said control means includes a selectively actuatable accumulator, said actuatable accumulator being located within said hydraulic fluid circuit between  
5 said first piston assembly and said second piston assembly.

65. The actuating system according to Claim 1, wherein said energy transfer means comprises a rocker arm and an hydraulic fluid circuit integrated therein, and said valve actuation means includes a piston assembly integrated into said rocker arm, said piston assembly including a stem-shaped piston.

66. The actuating system according to Claim 64, wherein said selectively actuatable accumulator is in a locked position during one operating mode.

67. The actuating system according to Claim 65, wherein said stem-shaped piston is in a locked position during one operating mode.

68. The actuating system according to Claim 1, wherein said energy transfer means is connected to said valve actuation means, said energy transfer means having a first piston assembly located therein, and said valve actuation assembly having a second piston assembly located therein.

69. The actuating system according to Claim 68, wherein said valve actuation means, said energy transfer means and said control means cooperate to provide lost motion valve actuation of the at least one valve.

70. The actuating system according to Claim 68, wherein at least a portion of said control means is located within said energy transfer means between said first and second pistons.

71. The actuating system according to Claim 70, wherein said control means includes a third piston assembly, wherein said third piston assembly is located intermediate of said first and second piston.

72. The actuating system according to Claim 68, further comprising:  
clipping means for clipping movement of one of said first and second pistons.

73. The actuating system according to Claim 1, wherein said valve actuation means, said energy transfer means and said control means are positioned within a rocker arm assembly.



74. The actuating system according to Claim 73, wherein said valve actuation means, said energy transfer means and said control means cooperate to provide lost motion valve actuation of the at least one valve.

75. The actuating system according to Claim 74, wherein said control means includes a selectively actuatable accumulator for controlling the amount of energy transferred to said valve actuation means during the plurality of engine operating conditions.

76. The actuating system according to Claim 75, wherein said control means includes supply means for supplying a fluid to said selectively actuatable accumulator.

77. The actuating system according to Claim 76, wherein said control means further includes venting means for venting the fluid from said selectively actuatable accumulator at a predetermined time.

78. The actuating system according to Claim 77, wherein said venting means vents said fluid to a fluid recovery system.

79. The actuating system according to Claim 78, wherein said fluid recovery system is connected to an additional accumulator assembly.

80. The actuating system according to Claim 78, wherein said fluid recovery system is connected to said supply means.

81. The actuating system according to Claim 78, wherein said fluid recovery system is connected to a reservoir.

82. The actuating system according to Claim 78, wherein said fluid recovery system is connected to a supplemental fluid supply.

83. The actuating system according to Claim 82, wherein said supply means further includes supply control means for controlling the supply of fluid to said selectively actuatable accumulator.

84. The actuating system according to Claim 83, wherein said supply control means includes a valve assembly to control the supply of fluid to said selectively actuatable accumulator.

85. The actuating system according to Claim 84, wherein said supplemental fluid supply is selectively operable to control said valve assembly.

86. The actuating system according to Claim 1, wherein said valve actuation means, said energy transfer means and said control means are positioned within a hydraulic overhead assembly.

87. The actuating system according to Claim 86, wherein said valve actuation means, said energy transfer means and said control means cooperate to provide lost motion valve actuation of the at least one valve.

88. The actuating system according to Claim 87, wherein said control means includes a selectively actuatable accumulator for controlling the amount of energy transferred to said valve actuation means during the plurality of engine operating modes.

89. The actuating system according to Claim 88, wherein said control means includes supply means for supplying a fluid to said selectively actuatable accumulator.

90. The actuating system according to Claim 89, wherein said control means further includes venting means for venting the fluid from said selectively actuatable accumulator at a predetermined time.

91. The actuating system according to Claim 90, wherein said venting means vents said fluid to a fluid recovery system.

92. The actuating system according to Claim 91, wherein said fluid recovery system is connected to an additional accumulator assembly.

93. The actuating system according to Claim 91, wherein said fluid recovery system is connected to said supply means.

94. The actuating system according to Claim 91, wherein said fluid recovery system is connected to a reservoir.

95. The actuating system according to Claim 91, wherein said fluid recovery system is connected to a supplemental fluid supply.

96. The actuating system according to Claim 95, wherein said supply means further includes supply control means for controlling the supply of fluid to said selectively actuatable accumulator.

97. The actuating system according to Claim 96, wherein said supply control means includes a valve assembly to control the supply of fluid to said selectively actuatable accumulator.

98. The actuating system according to Claim 97, wherein said supplemental fluid supply is selectively operable to control said valve assembly.

99. The actuating system according to Claim 1, wherein said valve actuation means includes a means for automatically taking up lash.

100. In an hydraulic valve actuation system for operating at least one valve of an engine during a plurality of engine operating conditions, wherein the valve actuation system includes a cam assembly having a plurality of lobes formed thereon for supplying motion to operate the at least one valve during the plurality of engine operating conditions, a valve actuating assembly having a first piston assembly for actuating the at least one valve, and a motion transfer assembly having a second

piston assembly and a hydraulic circuit for transferring the motion from said cam assembly to said first piston assembly, the improvement comprising:

control means for controlling the amount of motion transferred from said motion transfer assembly to said first piston assembly to control the actuation of the at least one valve during the plurality of engine operating conditions.

101. The valve actuation system according to Claim 100, wherein said control means includes a selectively actuatable accumulator for controlling the amount of motion transferred to said first piston assembly during the plurality of engine operating conditions.

102. The valve actuation system according to Claim 101, wherein said selectively actuatable accumulator is in a locked position during one operating mode such that all of the motion from said cam assembly is transferred to said slave piston assembly.

103. The valve actuation system according to Claim 102, wherein said selectively actuatable accumulator has a fixed volume.

104. The valve actuation system according to Claim 102, wherein said selectively actuatable accumulator is in an unlocked position during another operating mode such that only a portion of the motion from said cam assembly is transferred to said first piston assembly.

105. The valve actuation system according to Claim 104, wherein said control means includes supply means for supplying a fluid to said selectively actuatable accumulator.

106. The valve actuation system according to Claim 105, wherein said control means further includes venting means for venting a predetermined amount of fluid from said selectively actuatable accumulator at a predetermined time.

107. The valve actuation system according to Claim 105, wherein said control means further includes venting means for venting a predetermined amount of fluid from said selectively actuatable accumulator at a predetermined position of said first piston assembly.

108. The valve actuation system according to Claim 105, wherein said control means further includes venting means for venting a predetermined amount of fluid from said selectively actuatable accumulator at a predetermined position of said second piston assembly.

109. The valve actuation system according to Claim 105, wherein said supply means supplies fluid to said selectively actuatable accumulator to maintain said accumulator in a locked position in one operating mode.

110. The valve actuation system according to Claim 109, wherein said supply means further includes supply control means for controlling the supply of fluid to said selectively actuatable accumulator.

111. The valve actuation system according to Claim 110, wherein said control means further includes selectively operable fluid supply means for selectively supplying fluid to said supply means.

112. The valve actuation system according to Claim 111, wherein said selectively operable fluid supply means selectively operates said supply control means.

113. The valve actuation system according to Claim 111, wherein said control means further includes selectively operable fluid supply means for selectively operating said supply control means.

114. The valve actuation system according to Claim 113, wherein said selectively operable fluid supply means selectively supplies fluid to operate said supply control means.

115. The valve actuation system according to Claim 114, wherein said control means further includes venting means for venting a predetermined amount of fluid from said selectively actuatable accumulator at one of a predetermined time, a predetermined position of said master piston assembly and a predetermined position of said first piston assembly.

116. The valve actuation system according to Claim 115, wherein said supply control means includes a valve assembly to control the supply of fluid to said selectively actuatable accumulator and said venting means.

117. The valve actuation system according to Claim 115, wherein said venting means vents a predetermined amount of fluid from said supply means to release said selectively actuatable accumulator from said locked position.

118. The valve actuation system according to Claim 117, wherein said venting means vents a predetermined amount of fluid to the atmosphere during one operating mode.

119. The valve actuation system according to Claim 118, wherein said venting means vents a predetermined amount of fluid to a recovery system during one operating mode.

120. The valve actuation system according to Claim 118, wherein said venting means vents a predetermined amount of fluid to an additional accumulator assembly during one operating mode.

121. The valve actuation system according to Claim 100, wherein said control means includes a selectively actuatable accumulator, said actuatable accumulator being located within said second piston assembly.

122. The valve actuation system according to Claim 121, wherein said selectively actuatable accumulator is in a locked position during one operating mode.

123. The valve actuation system according to Claim 100, wherein said control means includes a selectively actuatable accumulator, said actuatable accumulator being located within said first piston assembly.

124. The valve actuation system according to Claim 123, wherein said selectively actuatable accumulator is in a locked position during one operating mode.

125. The valve actuation system according to Claim 100, wherein said control means includes a selectively actuatable accumulator, said actuatable accumulator being located within said hydraulic fluid circuit between said second piston assembly and said first piston assembly.

126. The valve actuation system according to Claim 125, wherein said selectively actuatable accumulator is in a locked position during one operating mode.

127. The valve actuation system according to Claim 100, wherein said valve actuating assembly, said motion transfer assembly and said control means cooperate to provide lost motion valve actuation of the at least one valve.

128. The valve actuation system according to Claim 100, wherein said valve actuation system provides for lashless valve actuation.

129. In an hydraulic valve actuation system, a method of controlling the amount of lost motion between an actuating assembly for actuating at least one valve and the at least one valve during a plurality of engine operating conditions, wherein the actuating assembly includes a cam assembly for providing motion to actuate at least one valve, a first piston assembly in communication with the cam assembly, a second piston assembly selectively in communication with the at least one valve for operating the at least one valve, and a hydraulic circuit communicating between the second piston assembly and the first piston assembly, said method comprising the steps of:

providing a selectively actuatable accumulator with the actuating assembly; and

supplying fluid to said selectively actuatable accumulator to establish a predetermined volume of fluid with said selectively actuatable accumulator.

130. A method for actuating at least one valve of an engine during a plurality of engine operating conditions, said method comprising the steps of:

supplying energy from an energy supply to operate the at least one valve during the plurality of engine operating conditions;

5       transferring energy from the energy supply to a valve actuation assembly to actuate the at least one valve; and

          controlling the amount of energy transferred from the energy supply to the valve actuation assembly to control the actuation of the at least one valve during the plurality of engine operating conditions.

131. The method according to Claim 130, wherein said step of controlling the amount of energy transferred from the energy supply to the valve actuation assembly includes the step of selectively actuating an accumulator for controlling the amount of energy transferred to the valve actuation assembly.

132. The method according to Claim 131, further comprising the step of locking the accumulator during one operating mode such that all of the energy from the energy supply is transferred to the valve actuation assembly.

133. The method according to Claim 131, further comprising the step of unlocking the accumulator during one operating mode such that only a portion of the energy from the energy supply is transferred to the valve actuation assembly.

134. The method according to Claim 131, further comprising the step of controlling the supply of fluid to the accumulator.

135. The method according to Claim 131, further comprising the step of supplying a fluid to the accumulator to control the amount of energy transferred to the valve actuation assembly.

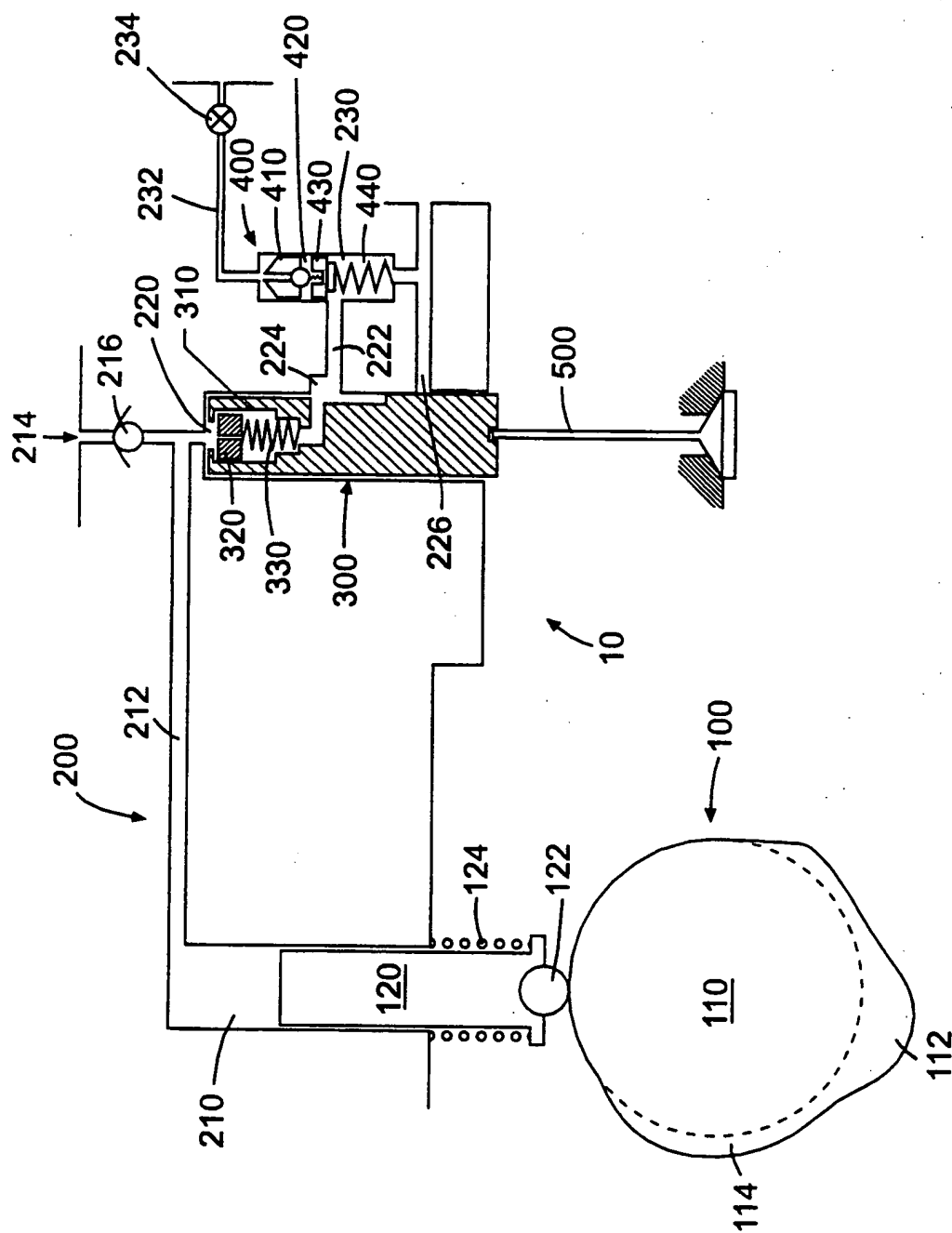
136. The method according to Claim 135, further comprising the step of venting the fluid from the accumulator at a predetermined time.

137. The method according to Claim 136, wherein the valve actuation assembly includes a piston assembly, and wherein said step of venting the fluid occurs at a predetermined position of the piston assembly.

138. The method according to Claim 135, wherein said step of transferring energy includes the step of providing an energy transfer assembly having a piston assembly and a hydraulic circuit for transferring energy from the energy supply to the valve actuation assembly, wherein said step of venting the fluid occurs at a predetermined position of the piston assembly.

139. The method according to Claim 135, wherein said step of venting includes the step of venting a predetermined amount of fluid to release the accumulator at predetermined engine operating conditions.

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**FIG. 1**

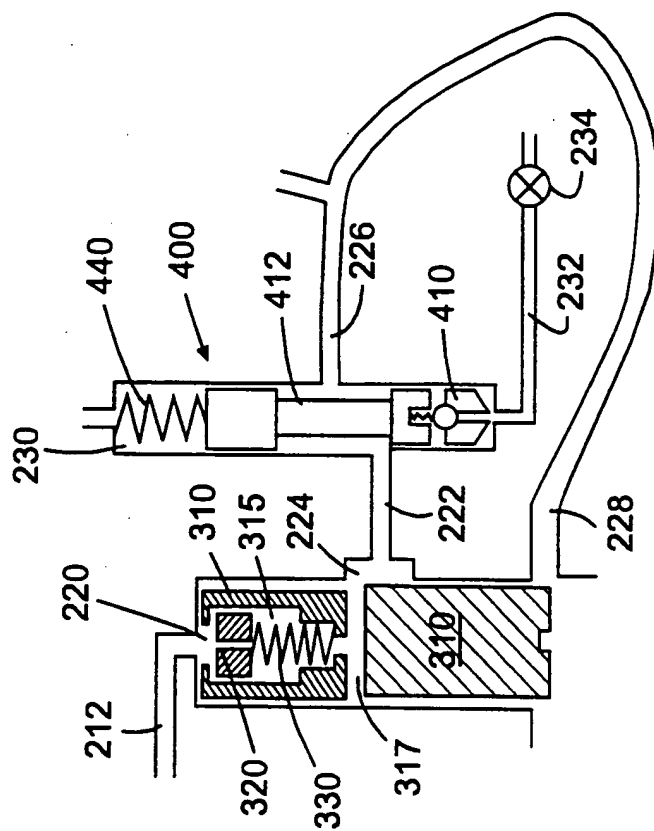


FIG. 2

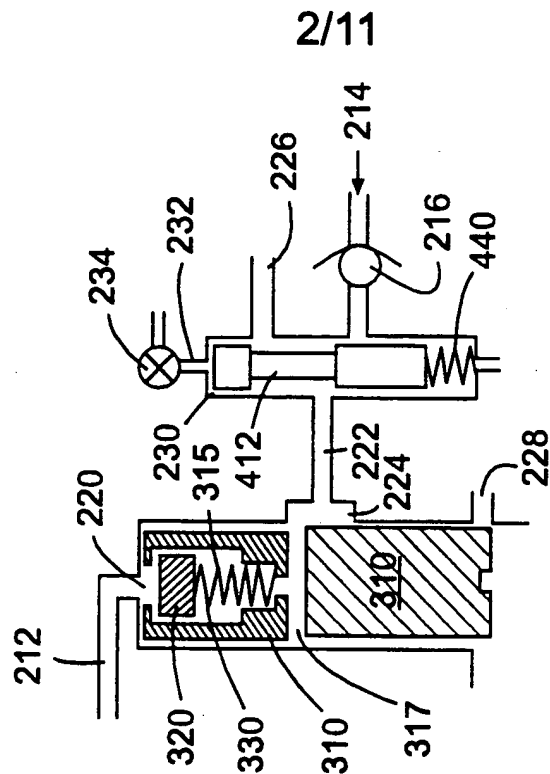


FIG. 3



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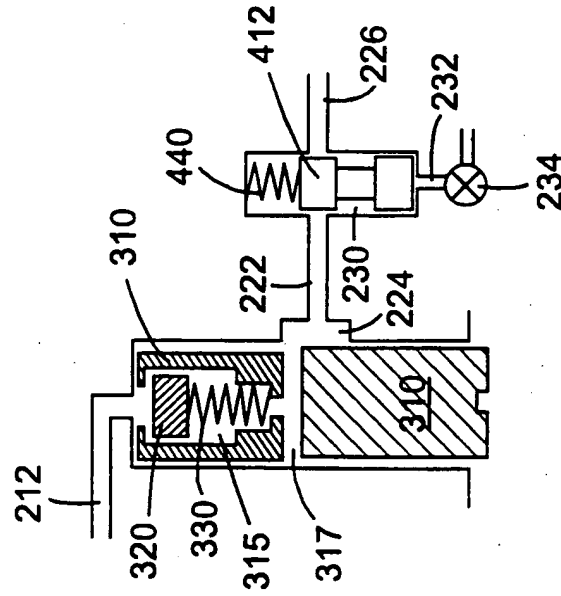


FIG. 5

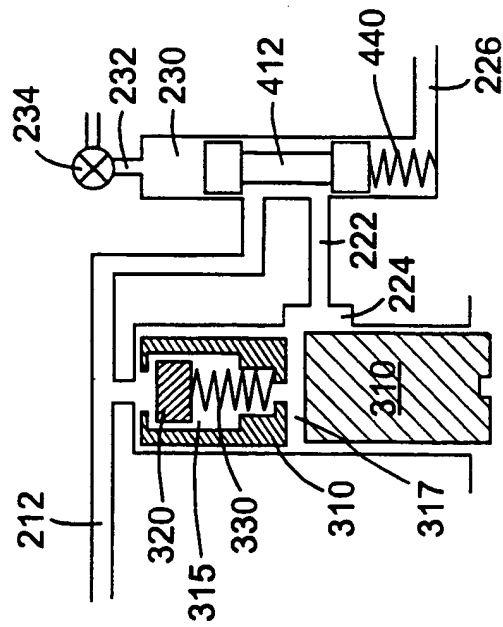


FIG. 4

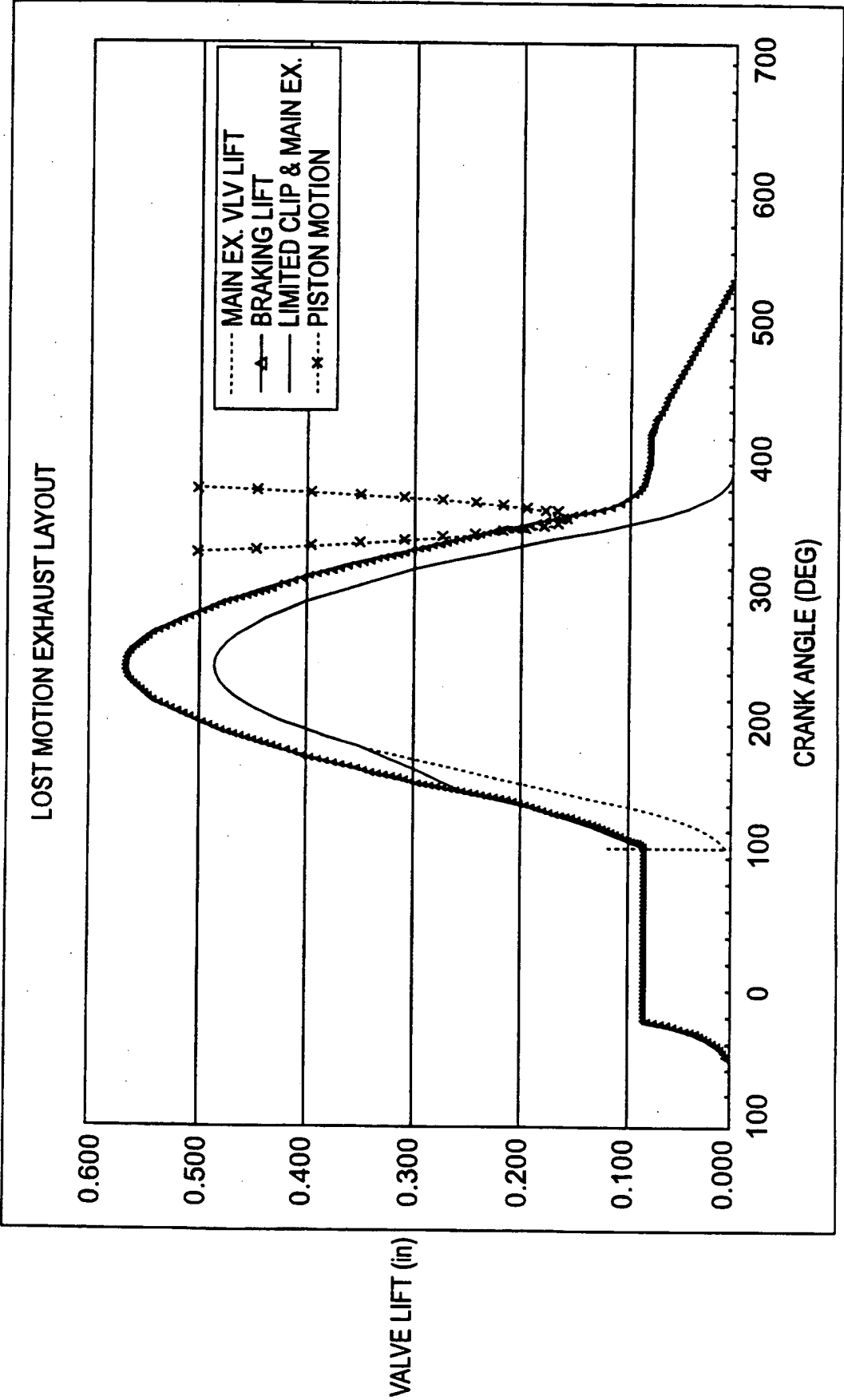
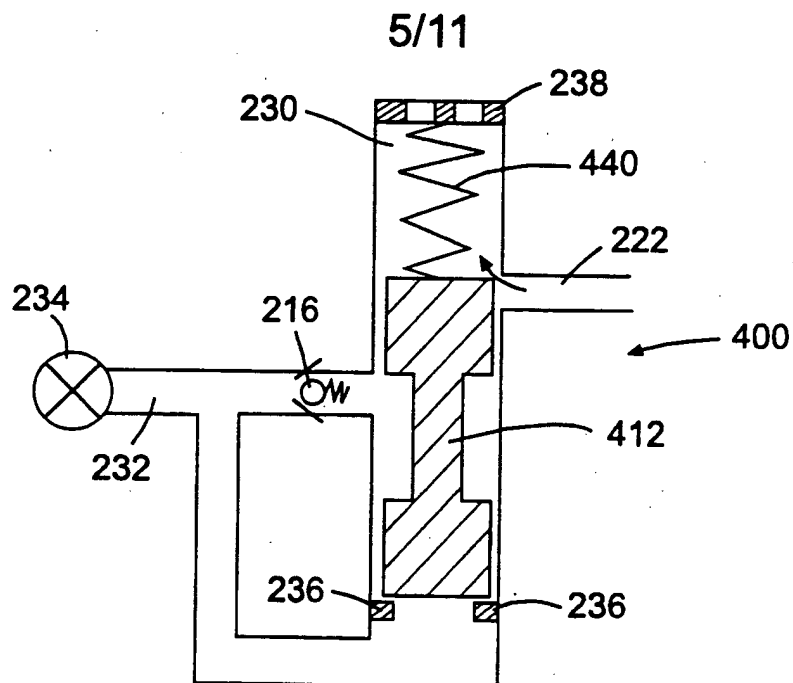
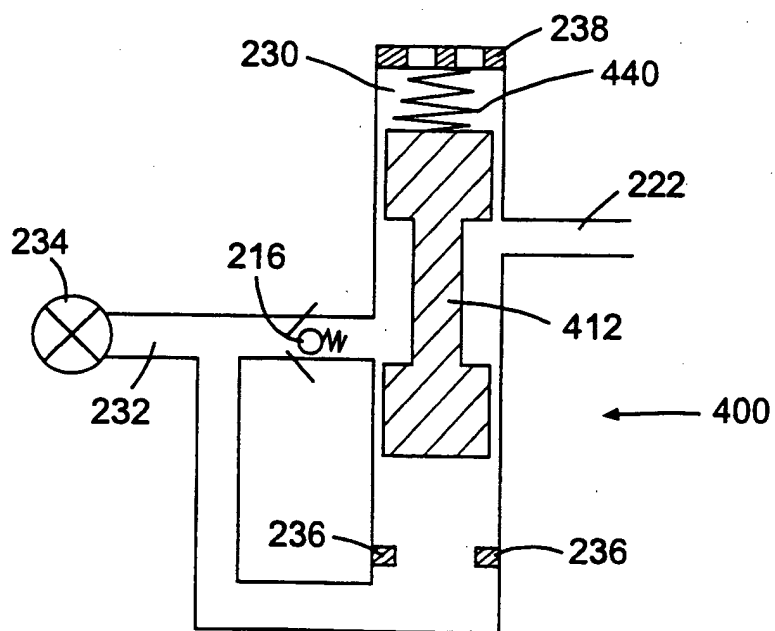


FIG. 6



**FIG. 7**



**FIG. 8**

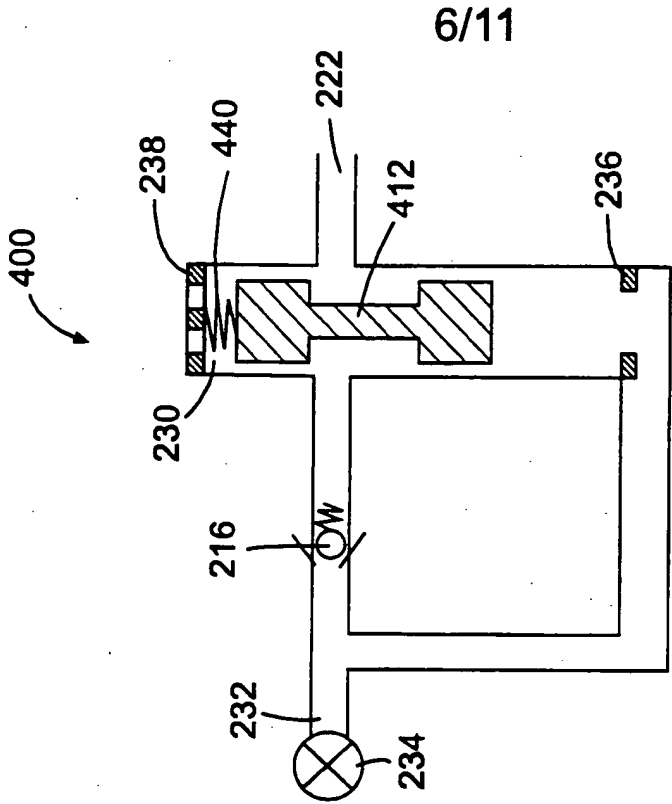


FIG. 9

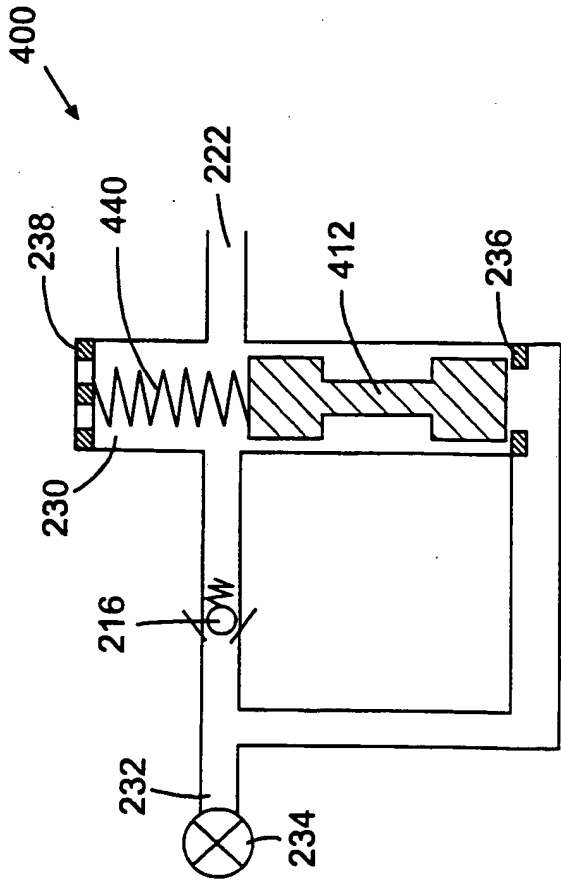


FIG. 10

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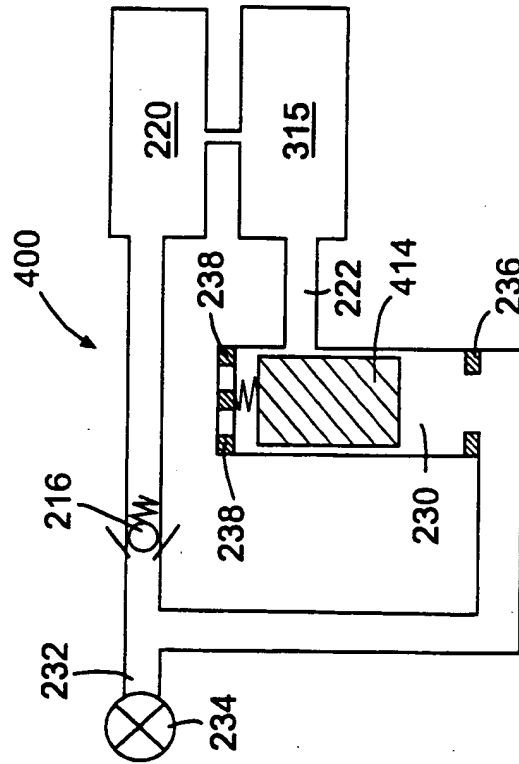


FIG. 11

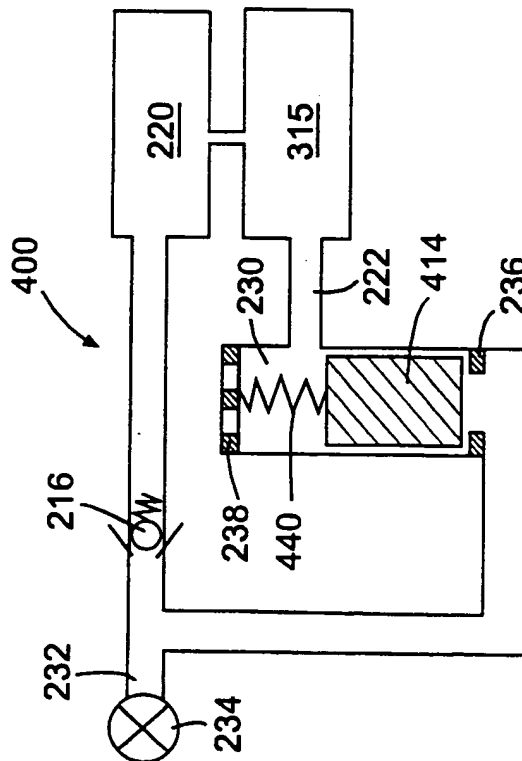
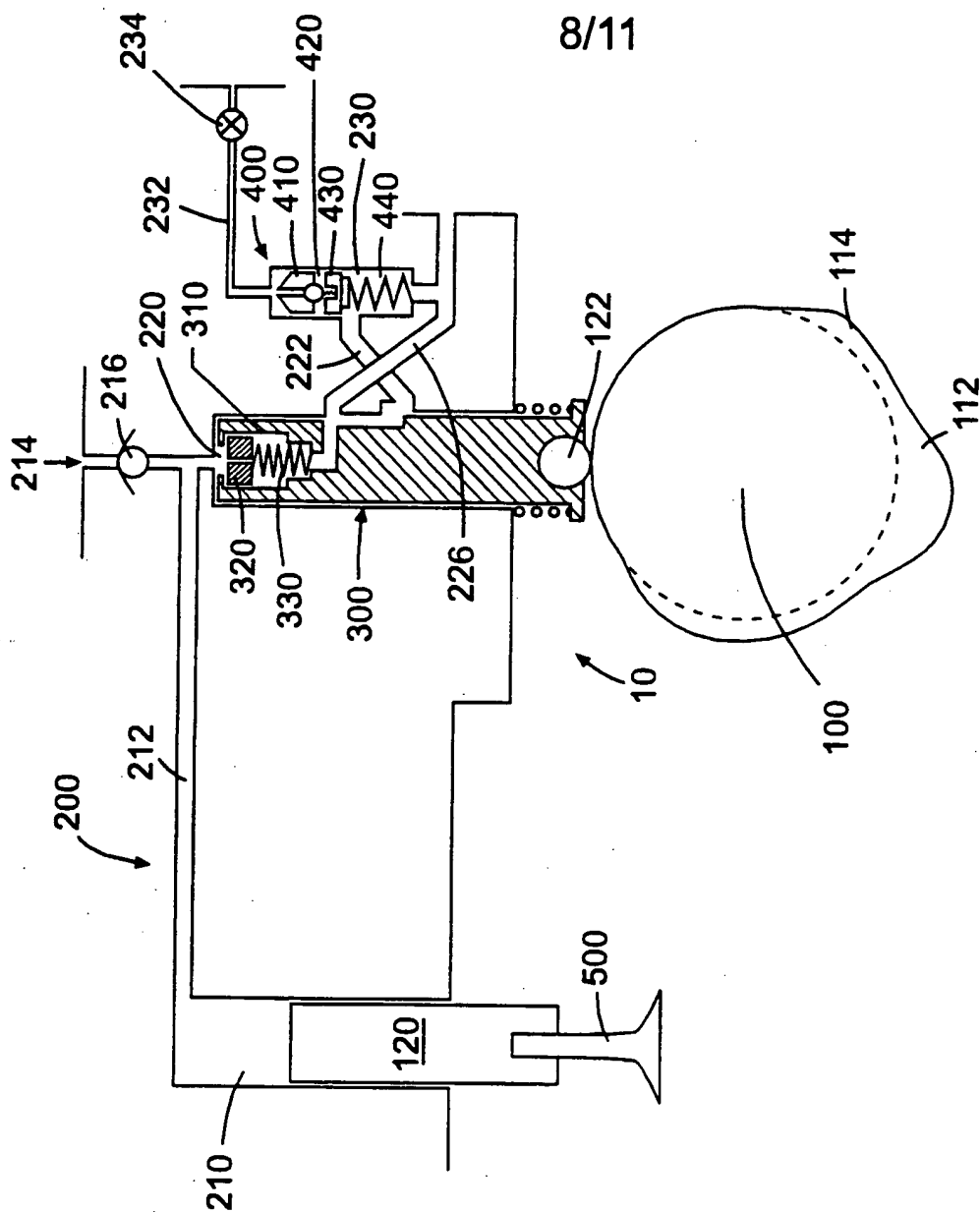
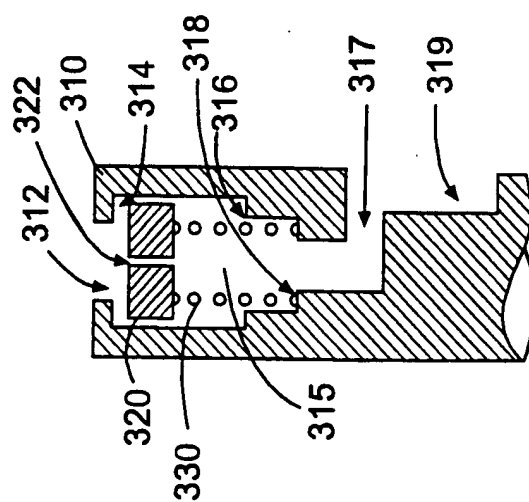


FIG. 12



**FIG. 14**



**FIG. 13**

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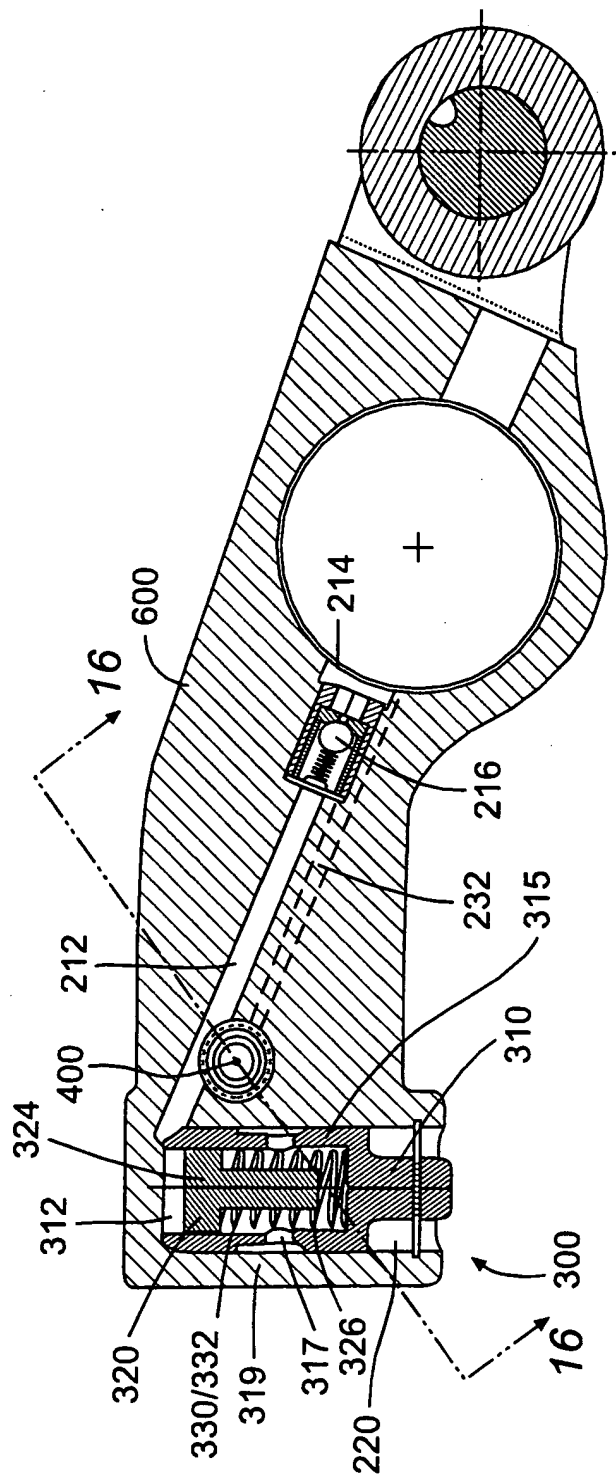


FIG. 15

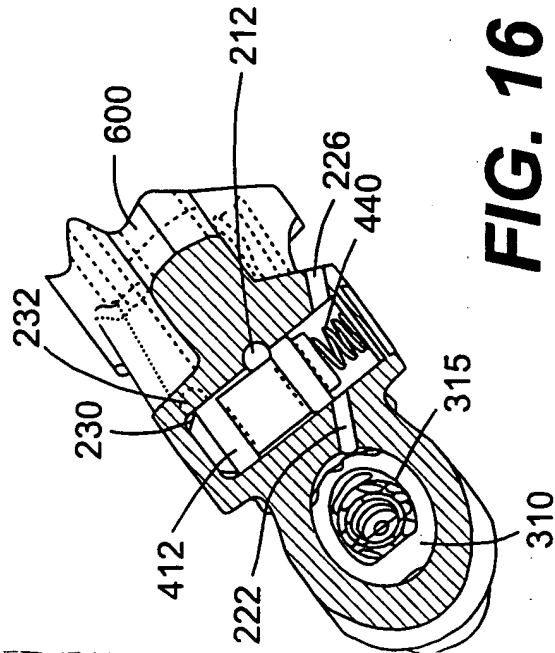
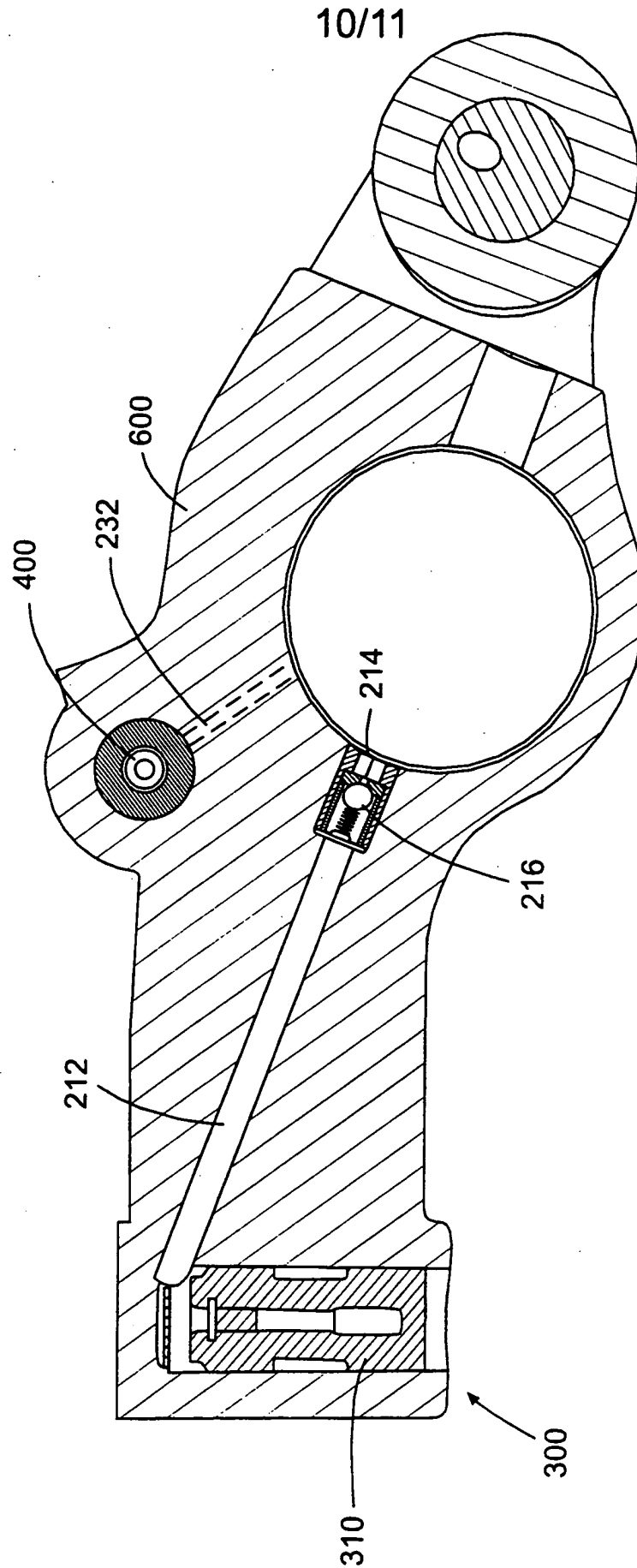


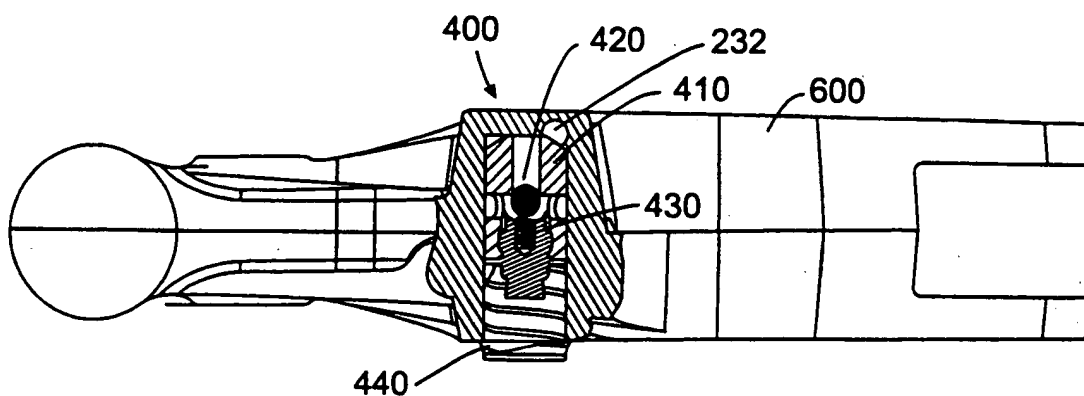
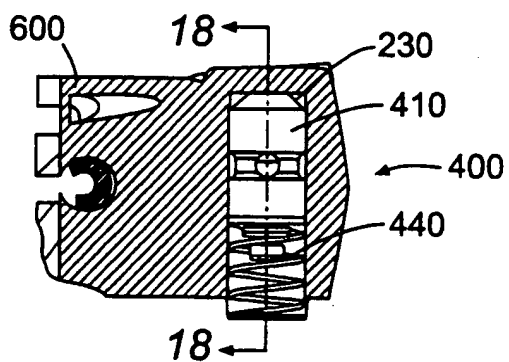
FIG. 16



**FIG. 17**



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**FIG. 18****FIG. 19**

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/25298

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : F02D 13/04; F01L 1/34  
US CL : 123/321, 90.15

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 123/321, 90.15, 322, 90.11, 90.12, 90.16, 90.17

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
Please See Continuation Sheet

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-----------------------|
| X          | US 5,680,841 A (HU) 28 October 1997 (28.10.1997), see figure 1                     | 1,130                 |
| ---        |  |                       |
| Y          |  | 2-129,131-139         |
| Y          | US 5,105,782 A (MENEELY) 21 April (21.04.1992), see entire document.               | 1-139                 |

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

\* Special categories of cited documents:

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document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

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Date of the actual completion of the international search

01 December 2000 (01.12.2000)

Date of mailing of the international search report

18 DEC 2000

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Authorized officer

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Telephone No. (703)308-0861

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/25298

## Continuation of B. FIELDS SEARCHED Item 3: BRS

searched terms: valve, lost motion, intake, exhaust, timing, accumulator